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Fracture Patterns at the Medieval Leper Hospital in Chichester

MARGARET A. JUDD[1]* AND CHARLOTTE A. ROBERTS[2]
[1]*Department of Anthropology, University of Alberta, Edmonton, Alberta, Canada T6G 2H4*
[2]*Department of Archaeological Sciences, University of Bradford, Bradford, West Yorkshire, England BD7 1DP*

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ABSTRACT Humans are constantly at risk of bone fractures, not only when threatened by personal violence, but also by the challenge of daily living. Because fractures are a cross-cultural phenomenon and are one of the more commonly observed skeletal lesions in archaeological collections, their presence provides a unique opportunity to compare living conditions, and thereby assess fracture risk in coexisting cultures. This study analyzed long bone fracture patterns of 212 sexed adults from the medieval leper hospital of St. James and St. Mary Magdalene in Chichester, England. The comparison of this hospital sample to other British medieval skeletal samples examined the level of health manifest in fracture etiology. The fracture frequency for this sample was 15.1%, with males accounting for 85.4% of the fractures. The fracture frequencies from the samples not affiliated with hospitals ranged from 3.3 to 5.6%. Because medieval urban lifestyle was notoriously difficult due to inadequate sanitation and living conditions, the overall health of the population at large was inferior, placing all at similar fracture risk. Therefore, more specific complications associated with the fractures were examined. Osseous modifications of the skeletons due to lepromatous leprosy were associated with 28% of individuals sustaining fractures. However, persons with the milder tuberculoid leprosy do not exhibit skeletal lesions, but are more prone to accident due to the earlier loss of sensory perception and visual impairment. It is argued that the presence of leprosy is underestimated in archaeological populations and may be a major contributing factor to the prevalence of fracture resulting from accidental falls. Am J Phys Anthropol 105:43–55, 1998.

Fractures are one of the most common pathological lesions in archaeological skeletal populations, next to dental disease and osteoarthritis. However, very few studies have been conducted on this type of trauma when compared to the abundant literature on dental and osteoarthritic research. Earlier fracture studies were broadly based, using only small skeletal samples spanning a vast period of time (e.g., Angel, 1974; Grimm, 1980). These investigations assumed that violence was the primary cause of fractures without regard for more proximate intrinsic or extrinsic factors. Although fractures attributed to violence, especially cranial lesions, remain topical (e.g., Filer, 1992; Bloom and Smith, 1991), populational investigations devoted exclusively to fracture analysis have become important by focusing on the biocultural interpretation of fractures (e.g., Lovejoy and Heiple, 1981;

*Correspondence to: Margaret A. Judd, Department of Anthropology, 13-15 Tory Building, University of Alberta, Edmonton, Alberta, Canada T6G 2H4. Fax: (403) 492-5273. E-mail: mjudd@gpu.srv.ualberta.ca

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Judd, 1994; Grauer and Roberts, 1996). This holistic interpretation of fracture etiology has also become predominant in the traditional skeletal report (e.g., Stroud and Kemp, 1993; Lilley et al., 1994).

Clinical studies have ascertained that biological factors such as age, deteriorating senses (vision, hearing, etc.), osteoporosis, reduced bone mass due to inactivity, and poor health predispose the individual to fracture during routine actions (e.g., Buhr and Cooke, 1959; Knowelden et al., 1964; Garroway et al., 1979; Matkovik et al., 1979; Fife and Baranic, 1985; Mensforth and Latimer, 1989; Donaldson et al., 1990; Jónsson et al., 1992; Madhok et al., 1993). Research with modern populations has demonstrated that environmental factors such as geographic location (Jónsson et al., 1992; Madhock et al., 1993); climate (Ralis, 1986); technological level (Jones, 1990); occupation and sports (Björnstig et al., 1991; Cogbill et al., 1991); and domestic life (Aström et al., 1987; Johansson et al., 1991) also play a dominant role in fracture etiology. The performance of daily routine activities and deteriorated health, both catalysts for accidental falls, are the primary explanations of fracture in modern populations even though our society has excelled in technological and medical discoveries. By analogy, habitual daily activities and poor health must also account for some fractures in antiquity.

Interpopulational comparisons between contemporary societies provide a window through which the fracture risk of a group can be closely examined. Fracture risk can be described quantitatively by the fracture frequency of the sample, i.e., the number of fractures per bones or individuals observed. Based on the same principle, risk of fracture can be further extended to include specific bones or the individual's sex. If there is a large disparity in the fracture frequency between populations or bones, then one group, either people or bones, is at a higher fracture risk. The differences can be attributed to activity, demographic distribution, health, living conditions or a combination of these factors. Therefore, it is expected that the hospital sample, with the majority of individuals suffering from some form of incapacitation, would exhibit a higher fracture frequency due to greater risk of fracture.

In addition to the traditional problems in osteological investigations (i.e., poor bone preservation, interobserver error, recording variations, difficulties in aging adults and radiographic distortion) there are limitations unique to fracture interpretations in archaeological populations:

1) Fractures are cumulative and therefore the age of occurrence is unknown. While the stage of healing provides an estimate of when a *recent* fracture occurred relative to the age at death, an older, well-healed fracture cannot be assigned an age of occurrence.
2) It is unknown in which geographic location the individual sustained the fracture and under what circumstances. Therefore, an under- or overestimation of a group's fracture frequency is possible based on immigration and emigration patterns. In this case, for example, it is assumed that the fracture occurred while the person was resident in the hospital.
3) The detection of fractures can be hampered by obliterated evidence of fracture due to superior healing or ambiguity between perimortem fracture and postmortem bone trauma (Grauer and Roberts, 1996).
4) Finally, the inability to determine whether complications, such as osteoarthritis or infections, were causative factors in the fracture etiology or a result of the fracture also poses a problem in fracture analysis.

Mindful of these constraints, the comparison of fracture patterns between hospital and normal skeletal samples serves a purpose. Based on the clinical studies mentioned above, it is known that accidental falls during the performance of daily activities and falls predisposed by deteriorated health, rather than violence, account for the majority of fractures in modern populations. Therefore, by examining an archaeological hospital sample, we may be able to determine the role of health in fracture patterns in ancient populations.

TABLE 1. Demography of the Chichester adults

Age at death (years)	Females		Males		Total	
	n	%	n	%	n	%
18–24	15	20.5	34	24.5	49	23.1
25–34	22	30.1	39	28.0	61	28.8
35–44	28	38.4	44	31.7	72	33.9
45+	5	6.9	11	7.9	16	7.6
Undetermined	3	4.1	11	7.9	14	6.6
Totals	73	100.0	139	100.0	212	100.0

MATERIALS AND METHODS

The sample

The skeletal material studied in this investigation derived from the medieval hospital cemetery of St. James and St. Mary Magdalene in Chichester, England. The excavation was conducted by the Chichester District Archaeological Unit from 1986 to 1987 in preparation for a housing project. A preliminary report of the excavation explains that the cemetery can be divided into three discrete areas of use that reflect the change in this hospital's function, from lazarium to almshouse, during the 12th to 17th centuries (Magilton and Lee, 1989). Likewise, this transition is reflected in the demographic profile of the inhabitants. The chronology of the Chichester hospital and its community will be examined further in the Discussion.

Of 351 individuals excavated, 230 skeletons were those of adults. Age and sex were assigned to 198 adults by the principal investigator; 14 were of known sex only and 18 were of undetermined age and sex (Lee, n.d.). All adults of known sex, for a total sample size of 212 individuals, were included in this study (Table 1). Every observed fracture was assignable to biological sex.

Methodology

Each individual's long bones (clavicle, humerus, radius, ulna, femur, tibia and fibula) were recorded as present, incomplete or absent. The appearance of fractures was recorded for all present and incomplete bones. Fractures were determined to be postmortem, perimortem or antemortem.

In addition to a macroscopic description of the fracture, data collected for each fractured bone included the side affected; length of fractured bone; length of opposite bone; position of fracture (proximal, middle or distal third); relationship to skin surface (closed or open fracture); and fracture pattern (transverse, oblique, spiral, comminuted, impacted, compressed, hairline, avulsion and incomplete). The position and pattern of the fracture are suggestive of the type of force causing the injury, as well as the etiology of the fracture. The fracture area was examined for non-specific infection (periostitis and osteomyelitis) and the joint surfaces of surrounding bones were inspected to determine how the traumatized bone might influence joint movement (osteoarthritis, post-traumatic ossification and avascular necrosis). Also noted was whether the individual was afflicted with leprosy as determined by Magilton and Lee (1989).

Each fractured bone was sketched and radiographed anteroposteriorly and mediolaterally. The x-ray equipment used in the Archaeological Sciences Department at the University of Bradford was a Hewlett Packard Faxitron, model 43805. Paper used for x-rays was AGFA Structurix. Sixty kilovolts was applied for 2.25 minutes for radiographs of the clavicle, radius, ulna and fibula. Radiographs of the tibia, femur and humerus required 2.5 minutes at 60 kV.

Metrical data recorded from the radiographs included alignment, apposition and overlap of fragments, following the method most recently illustrated by Grauer and Roberts (1996). Alignment refers to the degree of angular or linear deformity created by the distally fractured bone segment from the axis. Apposition is the percentage of the horizontal surface area unified at the break site. Overlap is the amount of vertical displacement or shortening of the bone. These measurements may reflect the knowledge or the ability of the population to treat fractures. Poor reduction may suggest lack of skill, unavailability of treatment (an injury occurring away from assistance) or the characteristics of muscle strength (for example, muscles of the femur contract so strongly that it is difficult to reduce a fracture, i.e., pull the fragments apart to re-align). Unsuccessful healing consisting of complications of linear deformity and shortening were determined using the clinical model created by

TABLE 2. *Comparative medieval British urban cemetery populations*

Site	Date	Population[1]	Males	Females
Chichester	11–17th C	351	139	73
St. Helen-on-the-Walls[2]	10th C–1550	1041	247	285
St. Nicholas Shambles[3]	11th–12th C	234	90	71
Blackfriars[4]	1263–1538	250	148	64
Whithorn[5]	13th–15th C	1605	314	356

[1] Includes all excavated individuals.
[2] Grauer and Roberts, 1996 (subsequently referred to as St. Helen's).
[3] White, 1988 (subsequently referred to as St. Nicholas).
[4] Mays, 1991.
[5] Cardy, 1993.

TABLE 3. *Frequency of fractures at Chichester hospital*

Bone	Total bones	Number of fractured bones	%[1]	R + L total bones	R + L fractured bones	%
Clavicle						
R	128	4	3.1			
L	133	7	5.3	261	11	4.2
Humerus						
R	121	2	1.7			
L	122	0	0.0	243	2	.8
Ulna						
R	102	4	3.9			
L	115	2	1.7	217	6	2.8
Radius						
R	104	5	4.8			
L	114	2	1.8	218	7	3.2
Femur						
R	111	1	.9			
L	117	0	0.0	228	1	.4
Tibia						
R	141	4	2.8			
L	135	2	1.5	276	6	2.3
Fibula						
R	53	3	5.7			
L	58	5	18.6	111	8	7.2
Totals				1554	41	2.6

R = right; L = left.
[1] % = number of fractured bones/total number of bones × 100%.

Roberts (1988) and recently published by Grauer and Roberts (1996).

Once the data collection was completed and analyzed, the results were compared to fracture data published by other investigators of contemporary sites, which were not associated with hospitals. Table 2 summarizes the sites and the demographic distribution of the skeletal material.

RESULTS

The numbers of long bones and antemortem fractures observed from the *entire adult cohort* (230 individuals) in the Chichester sample are summarized in Table 3. Of the 1,554 bones examined, 41 were fractured (2.6%). In this group the fibula was at greatest fracture risk followed by the clavicle, radius, ulna and tibia. The hardier humerus and femur were rarely traumatized. These 41 fractures were distributed among 32 individuals or 13.9% of the adults.

The sexed adult sample

The demographic distribution of fractures is profiled for the 212 sexed individuals in Table 4. The fracture rate for the sexed sample was 15.1%, with 32 of 212 individuals sustaining fractures. Twenty-seven males (12.7% of 212 sexed individuals) and five females (2.4%) had fractures. No consistent increase in fracture accumulation with age could be ascertained, although the older adults, i.e., those over 35 years of age, did bear the majority of fractures (18 of 31).

The distribution of fractures among the fractured bones is recorded in Table 5. Males sustained 35 (85.4%) of the 41 fractures. Among males, the most frequently fractured bone was the clavicle, followed by the fibula. The femur was least frequently injured, with only one fracture recorded. Fractures to the ulna accounted for half (n = 3) of the fractures among females. The tibia and radius were the only other bones fractured in the female sample. A χ^2 analysis between biological sex and the presence or absence of fracture suggested a significant relationship at a .05 significance level ($\chi^2 = 4.4$, df = 1). The Cramer's V test (V = .145) indicates that this is a very weak relationship.

Seven persons, one female (CH94) and six males, exhibited multiple fractures. Two individuals (CH94 and CH223) had combined fractures of the radius and ulna (Fig. 1), while two others (CH157 and CH193) sustained simultaneous injury to the fibula and tibia (Fig. 2). Other individuals with multiple fractures included CH98 (both clavicles and left fibula), CH115 (both radii and right femur) and CH129 (left clavicle and ulna).

The positions and types of the fractures are tabulated in Table 6, while fracture complications are recorded in Table 7. The distal third of the bone was the most frequent fracture position (58.5%) and the proximal third least affected with only three

TABLE 4. Prevalence of fractures by age and sex distribution

Age at death (years)	Females			Males			Total		
	n	Fractures	%	n	Fractures	%	n	Fractures	%
18–24	15	1	6.7	34	6	17.6	49	7	14.3
25–34	22	0	0.0	39	6	15.4	61	6	9.8
35–44	28	3	10.7	44	11	25.0	72	14	19.4
45+	5	0	0.0	11	4	36.4	16	4	25.0
Totals[1]	70	4	5.7	128	27	21.1	198	31	15.7
Undetermined	3	1	33.3	11	0	0.0	14	1	7.1
Totals[2]	73	5	6.8	139	27	19.4	212	32	15.1
Sample	212	5	2.4	212	27	12.7	212	32	15.1

[1] Aged and sexed adults.
[2] All sexed adults.

TABLE 5. Prevalence of fractures by bone and sex at Chichester

Bone	Females			Males			Total	
	Fractures	%	%Total	Fractures	%	%Total	Fractures	%
Clavicle	0	0.0	0.0	11	31.4	26.8	11	26.8
Humerus	0	0.0	0.0	2	5.7	4.9	2	4.9
Ulna	3	50.0	7.3	3	8.6	7.3	6	14.6
Radius	1	16.7	2.4	6	17.1	14.6	7	17.1
Femur	0	0.0	0.0	1	2.9	2.4	1	2.4
Tibia	2	33.3	6.0	4	11.4	9.8	6	14.6
Fibula	0	0.0	0.0	8	22.9	19.5	8	19.5
Totals	6	100.0	14.6	35	100.0	85.4	41	100.0

Fig. 1. Associated left ulna and radius fracture (CH94).

fractures (7.3%). Of the eight fracture types, oblique fractures, indicative of indirect non-torsional forces, predominated (43.9%), followed by impacted (17.1%) and transverse (14.6%) fractures. Fractures to the distal third of the bone are associated with accidents due to falls, tripping or slipping. For example, during a sudden fall, the hand is quickly extended to break the fall. The result is often an oblique or impacted fracture of the forearm near the hand. Similarly, when going over on one's ankle due to an uneven surface or tripping, the ankle is sprained or the distal fibula breaks. An oblique fracture line reflects the displacement of the body over the bone shaft that absorbs the indirect force. Contrarily, the horizontal (transverse) fracture is the result

Fig. 2. Associated left tibia and fibula fracture (CH193).

TABLE 6. Fracture pattern analysis

Bone	Position on shaft			Fracture type						
	Prox	Mid	Dist	Trans	Obl	Imp	Comn	Spiral	Hair	Comp
Clavicle	0	6	5	3	6	2	0	0	0	0
Humerus	2	0	0	0	0	1	0	0	0	1
Ulna	0	1	5	1	3	0	0	1	0	0
Radius	0	2	5	1	2	2	0	1	1	0
Femur	0	0	1	0	1	0	0	0	0	0
Tibia	1	2	3	1	2	1	1	0	1	0
Fibula	0	3	5	0	4	1	2	0	0	1
Totals	3	14	24	6	18	7	3	2	2	2
% of total fractures (n = 41)	7.3	34.2	58.5	14.6	43.9	17.1	7.3	4.9	4.9	4.9

Prox = proximal 1/3; Mid = middle 1/3; Dist = distal 1/3; Trans = transverse fracture (horizontal fracture line due to direct blow); Obl = oblique fracture (diagonal fracture line due to combined force directions); Imp = impacted fracture (fractured fragments squeezed together and interlocked); Comn = comminuted fracture (bone is broken into fragments which can be counted); Spiral = spiral fracture (S-shaped fracture line due to torsional force); Hair = hairline fracture (non-displaced fracture often due to repetitive stress); Comp = compression fracture (bone is crushed into many pieces).

TABLE 7. Fracture complications

Bone	Def	Perios	Omyel	OA	Short	Mal	Ossif	Leprosy
Clavicle	6	2	0	1	2	1	0	5
Humerus	0	0	0	0	0	0	1	1
Ulna	0	1	0	2	1	0	0	0
Radius	1	3	0	4	1	1	0	2
Femur	0	0	1	1	0	1	0	1
Tibia	2	3	1	2	2	3	0	1
Fibula	2	3	0	0	0	0	0	1
Totals	11	12	2	10	6	6	1	11
% Fractures	26.8	29.3	4.9	24.4	14.6	14.6	2.4	26.8

Def = linear deformity; Perios = periostitis; Omyel = osteomyelitis; OA = osteoarthritis; Short = shortening; Mal = malunion; Ossif = post-traumatic ossification.

of a direct blow. Only one instance (2.4%) of an incomplete fracture occurred, while the other fracture types were present in more than one instance.

Non-specific infection was the most common complication, with periostitis (29.3%) dominating osteomyelitis (4.9%). Linear deformity (26.8%) and osteoarthritis (24.4%) were also prominent complications. However, non-specific infection and osteoarthritis, which affect 58.6% of the fractured bones, may be attributed to other factors such as

Fig. 3. Post-traumatic ossification of the right humerus and scapula (CH117).

habitual activity, other disease processes, age and gender. Only linear deformity, shortening, mal-union and ossification limit the individual's use of the limb and can be directly associated with the fracture. The more drastic post-traumatic ossification (Fig. 3) occurred only once in the sample and avascular necrosis was not observed. All fractures were antemortem and exhibited a well-formed callus in all but one instance (Fig. 4). Generally, the healing process was complete and successful; however, pain and discomfort can still be experienced but are impossible to determine from an archaeological sample.

Eleven (26.8%) of the 41 fractures occurred to individuals who displayed visible skeletal modifications due to lepromatous leprosy (Table 7). Because CH115 sustained three of these fractures (both radii and the right femur), leprous individuals who had fractures accounted for 28.1% (9 of 32) of individuals with fractures. In addition to these three fractures, one fracture occurred to each of the humerus, tibia and fibula, while 45.5% (5 of 11) of the clavicular fractures befell individuals suffering from leprosy (Fig. 5).

When the frequency of fractures was compared to other urban medieval British sites (Table 8), the results from the Chichester analysis far exceeded those of the other samples. The frequency of adults sustaining fractures was clearly unique at Chichester hospital, being on average three times as high. When fracture frequencies were compared by sex (Table 9), the prevalence of male fractures was higher than females in all cases and spanned a small range with the exception of Chichester (5.6–21.1%). Although the hospital sample also had the highest frequency of female fractures, the range of frequency was much narrower than the males (1.4–6.8%).

Tables 10 and 11 compare the distribution of fractures by bone type for the upper and lower body respectively. Among the fractures observed, the upper body exhibited more lesions than the lower limbs in all cases. Chichester hospital fracture frequencies exceeded those of the other samples for the clavicle and fibula, but were unexpectedly lower for the ulna, radius and humerus. Aside from a causal explanation, variation in this distribution is affected by differential data collection, the number of bones available to examine and the proportion of fractures per bone type to the number of fractures. For example, clavicular fracture data were unavailable for the St. Helen-on-the-

Fig. 4. Distal right femur fracture exhibiting poorly formed callus (CH115). This individual also exhibited osseous modifications due to lepromatous leprosy.

Walls sample; any clavicular fractures would lower the fracture frequencies of the other bones in the sample. Some samples had fewer fractures and subsequently exaggerated the frequency of fracture. In the case of St. Nicholas Shambles, two radii represented 25% of the eight fractures, while two fractured humeri from Chichester accounted for 4.9% of the 41 fractures. These type of results emphasize the need for a common recording methodology and publication of raw data, especially numbers of each bone type examined, types of fractures recorded, and distribution of fractures among the sexes.

DISCUSSION

Comparison between Chichester hospital and other medieval samples

When compared to other medieval urban samples, the fracture prevalence at Chichester was clearly distinctive. Living conditions for medieval townspeople were notoriously unfavorable, especially for the poor. Most lived in cheap, wooden tenements or one room wattle structures (Schofield and Vince, 1994) and were likely susceptible to falls due to overcrowding, poor lighting and construction. Others were not as fortunate, and exposed themselves to greater health risk by living on the streets. In addition to poor health and unsanitary living conditions, the urban poor were vulnerable to increased personal violence, also a product of crowded living conditions and poverty (e.g., Schofield and Vince, 1994). A high prevalence of fracture and trauma due to interpersonal violence may be expected under these conditions. However, in this study and in that of Grauer and Roberts (1996), it was found that the frequency of long bone fractures was extremely low among medieval urban samples except for Chichester, and that the fracture patterns were comparable to those due to accident rather than violence. Therefore some other factor must explain the higher frequency of fracture at Chichester hospital, especially since living conditions usually improved for the individual once admitted. Although agricultural involvement may account for a portion of the fractures, it is argued that the sensory impairments created by tuberculoid and lepromatous leprosy pose an additional fracture risk.

The medieval hospital

Chichester was a medieval urban center with a population of about 1,000 based on the Domesday Book records. Located on the low coastal plain, two miles from Sussex, it served as a market and port for the ships at

Fig. 5. Clavicular fractures (CH128, CH18, CH25); CH25 and CH128 both suffered from lepromatous leprosy.

TABLE 8. Comparison of fracture demography with other urban medieval sites

Site	Bones observed	Fractured bones	%	Sexed adults	Fractures[1]	%
Chichester	1554	41	2.6	212	32	15.1
St. Helen's	4938	41	.8	533	30	5.6
St. Nicholas	na	8	na	161	8	5.0
Blackfriars	1861	16	.9	212	14	6.6
Whithorn	9563	23	.2	670	22	3.3

[1] Individuals with fractures.

TABLE 9. Fracture frequencies by sex from urban medieval sites

Site	Females			Males		
	Total	Fractures	%	Total	Fractures	%
Chichester	73	5	6.8	139	27	21.1
St. Helen	285	11	3.9	247	18	7.3
St. Nicholas	71	3	4.2	90	5	5.6
Blackfriars	64	4	6.3	148	12	8.1
Whithorn	356	5	1.4	314	18	5.7

Dell Quay (Page, 1907). Most of the town's income was derived from trade rather than craft specialization and therefore many of the citizens were agriculturalists.

The English medieval hospital founded as early as 925 AD functioned as a guesthouse or shelter for travelers and pilgrims (Clay, 1909). By the end of the 11th century this charity was quickly extended to the poor, invalids, aged, fallen gentry and physically impaired, while some hospitals such as St. James and St. Mary Magdalene were constructed specifically to house lepers (Page, 1907). This institution was constructed during the reign of Henry I half a mile outside the east city gate based on the biblical decree in the Book of Leviticus (13:46): ". . . he is unclean: he shall dwell alone; without the camp shall his habitation be." The strategic position along the main road to London made the collection of alms from the public and wayfarers much easier, as charity was expected.

The composition of the hospital household consisted of the master, to administer the

TABLE 10. Distribution of upper body fractures in medieval urban sites

Site	Clavicle Fractures	Clavicle %[1]	Humerus Fractures	Humerus %	Ulna Fractures	Ulna %	Radius Fractures	Radius %
Chichester	11	26.8	2	4.9	6	14.6	7	17.1
St. Helen's	na	na	7	17.1	11	26.8	10	24.4
St. Nicholas	1	12.5	2	25.0	2	25.0	2	25.0
Blackfriars	1	6.3	2	12.5	4	25.0	4	25.0
Whithorn	4	17.4	2	8.7	2	8.7	5	21.7

[1] % = fractures of each bone type/total number of fractured bones × 100%.

TABLE 11. Distribution of lower body fractures in medieval urban sites

Site	Femur Fractures	Femur %[1]	Tibia Fractures	Tibia %	Fibula Fractures	Fibula %
Chichester	1	2.4	6	14.6	8	19.5
St. Helen's	1	2.4	6	14.6	6	14.6
St. Nicholas	0	0.0	1	12.5	0	0.0
Blackfriars	2	12.5	2	12.5	1	6.3
Whithorn	2	8.7	5	21.7	3	13.1

[1] % = fractures of each bone type/total number of fractured bones × 100%.

household; and staff to attend to the inmates, collect alms or provide domestic services such as cooking, cleaning, nursing, laundry or agricultural labor. Provision for the residents varied with the wealth or presence of a benefactor. In the well-endowed institutions bread and beer were plentiful, complemented by fresh meat, cheese, eggs, herring, butter and fresh vegetables. Fuel, linen and clothing were also supplied. Occasional monetary payments were made by the Crown to this hospital in its earlier years, circa 1158, when it functioned as a lazar house (Clay, 1909).

Originally eight leprous persons resided at St. James and St. Mary Magdalene's. However, by 1442 inmates were not ill or poor, but had bought their way into the hospital and spent evenings with their wives in the comfort of their own homes. Women were admitted around 1540, when the function changed to an almshouse. At the end of the 16th century, the inhabitants included the master, proctor and wife, along with 11 individuals (four males and seven females), either crippled or mentally handicapped (Page, 1907). Only one person was in residence at the close of the 17th century (Clay, 1909).

During the first three centuries of use, burials were predominantly leprous men, institutional masters, benefactors who requested burial there and possibly their wives or servants. The presence of females, children and non-leprous individuals increased as the function of the institution changed (Magilton and Lee, 1989). Because medieval hospitals also functioned as a lodge for travelers, non-indigenous individuals such as wanderers, merchants, foreigners and seafarers resided and possibly died here.

Fracture etiology at Chichester hospital

Not all individuals lodged at the hospital were bedridden, especially once the institution no longer functioned as a lazarium. After females were admitted with their children, childcare fell to the hospital if the mother died and the children were unable to support themselves. When the hospital functioned as an almshouse, hardier people, frequently children and the poor, were also resident and grew up there. These inhabitants were expected to assist in the maintenance of the hospitals by providing agricultural or domestic labor rather than begging. Some were therefore exposed to the risk of injury from farming, clinically regarded as one of the most hazardous occupations with or without modern mechanical equipment (i.e., Busch et al., 1986; Jones, 1990; Cogbill et al., 1991). Laborers were at additional risk to falls off horses and wagons; kicks from cows and horses; and falls from ladders and lofts. The fracture ratio of males to females was 5.4:1 at Chichester, slightly higher than the clinical ratio of 3:1 (Jones, 1990).

Due to the nature of this site, many of the fractures may be attributed to intrinsic factors of poor health associated with inadequate nutrition and clothing, a transient lifestyle and inadequate housing. Such individuals are more susceptible to periods of acute infection resulting in weakness, poor coordination and delayed reaction time and likely to encounter trauma due to domestic accidents. Modern clinical fracture studies reveal that such accidents rather than violence are the most common causes of fractures and are associated with oblique distal fractures due to the indirect force placed on

the lower bone when attempting to brace a fall. These "accidents" are frequently caused by physiological factors external to the bone structure, such as unexplained falls (drop seizures), failing eyesight, defective hearing, slow reaction-time, vertigo and impaired vibration sense in the lower limbs, and are usually associated with advanced age (i.e., Buhr and Cooke, 1959; Garroway, 1979; Donaldson et al., 1990; Zylke, 1990). However, all of these impairments are also directly associated with leprosy.

Leprosy

Leprosy is a chronic infection caused by *Mycobacterium leprae,* transmitted by aerosol droplets discharged into the atmosphere during talking, coughing or sneezing and inhaled. It is a disease of the nerves and can be incubated for up to 7 years, without exhibiting any visible changes to the body (Cochrane and Davey, 1964). The more devastating condition, lepromatous leprosy, is clinically manifest by lesions resulting from bone resorption and skin ulcerations (macules, papules and nodules), as well as sensory and motor dysfunction (Manchester, 1992).

When *Mycobacterium leprae* attack the nerves the body's communication system is interrupted. The milder form of the disease, tuberculoid leprosy, causes the nerve trunks to thicken and become inactive. Nerves typically affected include the medial, ulnar and radial nerves of the upper body; the common peroneal and posterior tibial nerves of the lower body; and the facial nerve (Srinivasan, 1993). These nerve trunks permit the transmission of external skin sensations to the brain and the corresponding muscular response to the sensation, as well as stimulate the sweat glands. The disruption of these transmissions disables skin sensitivity, dries the skin and weakens the muscles, making them susceptible to paralysis and deformation (Srinivasan, 1993). When the muscles become paralyzed the surrounding joints malfunction and take on new positions or even atrophy. The infection spreads to the joints of the hands, feet and ankle, predisposing the individual to mechanical failure of the hands and lower limbs, i.e., grasping, standing and walking, due to the additional stress (Cochrane and Davey, 1964).

The phalanges of the hand atrophy into a "claw-hand" deformation due to disuse. This arises because anesthesia and muscular weakness are simultaneous, allowing paralysis to set in rendering the hand dysfunctional. In contrast, the hands of individuals with lepromatous leprosy can be used for years while insensitive before weakness and paralysis occur. Therefore, they are more susceptible to injury from unfelt sensation, which may lead to phalangeal resorption beginning with the distal phalanges (Jopling and McDougall, 1988). Neither modification to the hands allows the person to successfully break a fall, but more likely results in a fracture to the forearm or clavicle if one purposefully lands on the shoulder to protect the handicapped hand.

The loss of sensation to the feet makes the individual vulnerable to clumsiness and falls due to uncoordination, obstacles and slippery surfaces. The paralysis of the posterior tibial nerve and its lower plantar nerves results in a loss of sensation to the entire sole of the foot. Paralysis of toe muscles causes the toes to curl under (claw-foot). Damage to the common peroneal nerve, which lifts the foot and toes while walking, affects the gait only slightly (Srinivasan, 1993). However, these individuals tend to lift their whole foot higher since the big toe cannot be lifted (drop-foot) and is in the way. If the foot is not lifted properly, the person will likely trip over his or her own feet, predisposing themselves to fracture, especially the lower leg.

Clinical studies have found that ocular leprosy is present in 30–35% of leprous patients, and may severely limit their daily routine. Susceptibility to blindness increases with the length of time that the disease is harbored by the individual and thus varies directly with age (Sehgal and Lamba, 1990). Persons suffering from tuberculoid leprosy experience visual difficulties early in the infection. Difficulty in closing the eyes (lagophthalmos) occurs when the 7th cranial nerve (facial nerve) is paralyzed, causing the eyeball to roll up in an attempt to shut the eyes and prevent corneal injury (Sehgal and Lamba, 1990). Damage to the 5th cranial

nerve (trigeminal nerve) results in corneal anesthesia, which means that the presence of irritating particles or injury may go unnoticed and lead to ulceration (Jopling and McDougall, 1988). Damage may be unilateral or bilateral and may affect both nerves, placing the eyes at greater risk of corneal ulceration, perforation and loss of vision (Sehgal and Lamba, 1990).

The more severe form of the disease, lepromatous leprosy, is manifest visually, frequently after an extended period of incubation up to 7 years (Manchester, 1992). Rather than remain in the nerve trunk, the bacilli invade the rest of the infected nerve, other nerves and tissue, which includes bone, by way of bodily fluids. As a result, the skin thickens, lesions erupt, edema develops, and bone is destroyed (Jopling and McDougall, 1988).

Large masses of infected tissue can overhang the eye and obstruct the vision or cause the lid to turn in and irritate the eyeball with the lashes (Cochrane and Davey, 1964). While the eye is not directly infected, the individual experiences visual deficiencies and is exposed to a greater risk of accidental falls. However, leprous bacilli can directly invade the eye through the bloodstream and the 5th cranial nerve, thereby infecting the cooler anterior areas of the iris, cornea and lens. These ocular infections may cause visual impairments ranging from slight interference, photophobia, blurred vision and eventually cause the structure to atrophy leading to blindness (Jopling and McDougall, 1988).

Bone modification to the face includes the resorption of the alveolar bone surrounding the maxillary incisors, resorption of the nasal spine and rounding of the nasal orifice (a result of nose collapse) and inflammation of the maxillae. This rhinomaxillary destruction is the primary osseous indicator of the presence of lepromatous leprosy. Bilateral insensitivity of the limbs due to subsequent nerve damage results in the mutilation and disintegration of the hands and feet from atrophy and resorption (Manchester, 1992). Because osseous modifications do not occur in many cases of leprosy, individuals institutionalized with tuberculoid leprosy or early dermal stages of lepromatous leprosy may go undetected during macroscopic skeletal examination and the presence of leprosy underestimated in archaeological samples.

CONCLUSIONS

The analysis of the long bone fractures from the Chichester leper hospital indicates that the frequency of fractured bones (2.6%) and the fracture rate among individuals (15.1%) are much higher than those of other urban medieval cemetery samples. In all cases, males exhibited more fractures and a greater diversity in fracture location. The majority of the Chichester fractures occurred to the clavicle and forelimbs, the etiology of which is attributed to accidental falls, based on the dominant pattern of distal oblique fractures.

In addition to the debilitating effect on the senses by poor health and living conditions, individuals with leprosy were also predisposed to accidental falls due to sensory deficiencies created by the disease. Approximately one-third of individuals with fractures exhibited the rhinomaxillary modifications of lepromatous leprosy. However, a milder form of leprosy, tuberculoid leprosy, does not affect the bone, but attacks soft tissue. Therefore the prevalence of individuals who suffered from sensory impairments caused by leprosy, especially vision, is underestimated. This hidden factor may explain a predisposition to accidental falls and thus a higher fracture rate at the leper hospital of St. James and St. Mary Magdalene in Chichester.

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